Proc. NIPR Symp. Antarct. Geosci., 6, 1-6, 1993

# ICEQUAKES RECORDED AT SYOWA STATION, ANTARCTICA

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***Abstract:*** Icequakes have been recorded by a three-component seismograph of short period at Syowa Station (69°S, 39°E), Antarctica since seismic observations were started in 1966. The icequakes are roughly classified into two groups from their waveforms: a high frequency type and a low frequency type. Icequakes of the high frequency type occurred about 1.8 times more than those of the low frequency type during the 24 months from February 1990 to January 1992. In the monthly numbers, there are some swarms, however, in daily numbers, only one icequake swarm of low frequency type was observed. A big tremor was also recorded during the swarm. All icequakes and tremors appear to originate in the continental ice sheet. Seismic observations at Syowa Station seem to be useful to monitor ice sheet movement.

## 1. Introduction

Many icequakes have been recorded by the three-component short period seismograph at Syowa Station (69°S, 39°E), Antarctica since 1966 when continuous monitoring of earthquakes was started. As shown in Fig. 1, Syowa Station is located on East Ongul Island, about 4 km away from the Antarctic continent.

KAMINUMA and HANEDA (1979) summarized three types of icequakes that were observed by a tripartite seismological network at Syowa Station during the period of temporary observations of the tripartite network on East Ongul Island from February 1976 to January 1977. The tripartite network is shown in Fig. 1. The types of icequakes are: 1) shocks with a sharp initial phase, 2) shocks with small or unidentified amplitude of an initial phase and 3) swarms. All the icequakes were estimated to be sea-ice shocks. They reported that no correlations were identified between icequake occurrences and either air temperature changes or oceanic tide. They also studied that the swarms were caused by an temperature changes.

KAMINUMA and TAKAHASHI (1975) reported the relation between icequake swarms and air temperature changes. The swarms were recorded by a vertical short period seismograph at Mizuho Camp (70.7°S, 44.3°E, 2180 m), an inland station in Antarctica. All icequakes seemed to be so called "thermal cracks".

AKAMATSU *et al.* (1990) detected about 4400 events by a seismic array around Syowa Station during the period from June 1987 to September 1988. The location

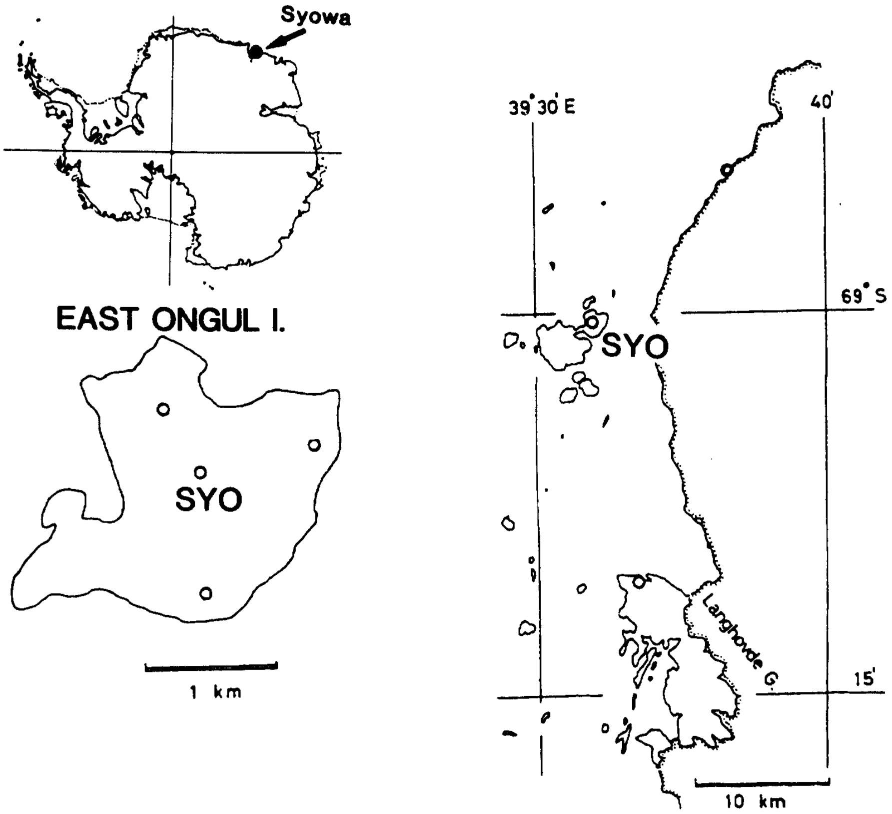


*Fig. 1. Location of Syowa Station. Open circles show locations of old seismic network presented by* AKAMATSU *et al. (1990).*

of the seismic array is also shown with open circles in Fig. 1. About 53% out of the 4400 events were icequakes ; another 33% were sea-ice shocks. Most of the icequakes were caused by glacier movements. A feature of icequakes recorded by the short period seismic monitoring at Syowa Station is discussed in this paper.

## 2. Two Types of Icequakes

Icequakes were detected on the monitoring seismogram of a three-component HES seismograph during 24 months from February 1990 to January 1992. There are some difficulties in distinguishing icequakes from earthquakes on seismograms, however, we have much experience in doing it from waveforms in the tripartite seismic observations around Syowa Station in 1987–1989 (AKAMATSU *et al.*, 1990). In this paper we discuss only the events which were detected as icequakes from their waveforms. As the local earthquakes around Syowa Station have mostly clear *P* and *S* phases, all other events are judged to be icequakes.

The icequakes recorded on the seismograms are roughly classified into two groups: a high frequency type and a low frequency type. Typical waveforms of the two types of icequakes are shown in Fig. 2. The high frequency type is characterized by waveforms with frequency of several hertz and short duration. The icequakes shown in Fig. 2(A) are examples of the high frequency type which have

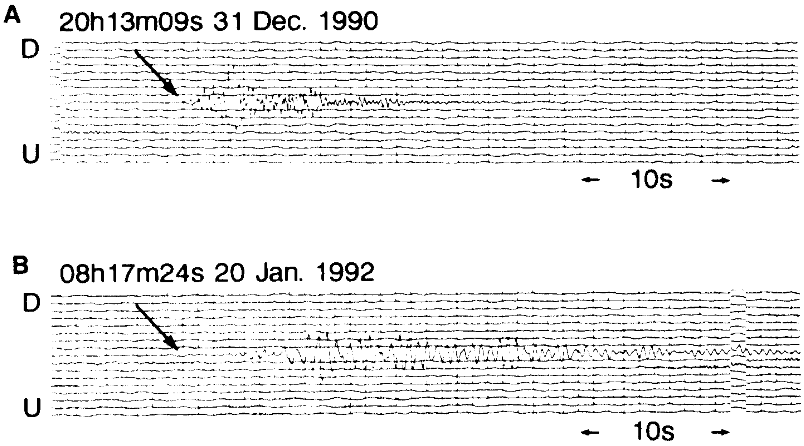


*Fig. 2. Seismograms of icequakes. (A) a high frequency type and (B) a low frequency type.*

frequency of 3-4 Hz and less than 30 s duration. The low frequency type has longer duration than the high frequency type. The icequake shown in Fig. 2(B) is an example of the low frequency type which occurred on January 20, 1992; it has a frequency of 1-3 Hz and more than 1 min duration.

Figure 3 shows the monthly numbers of icequakes of both high and low frequency types. About 1200 events of the high frequency type and about 2200 events of the low frequency type were recorded during 24 months. The average monthly number of the high frequency type is 50 icequakes. There are only five months that the monthly number of the high frequency type is over 100 events. An unusual number of 62 events was recorded on June 6, 1990, and 48 events per day on December 31, 1990; the usual number is less than 20 events per day.

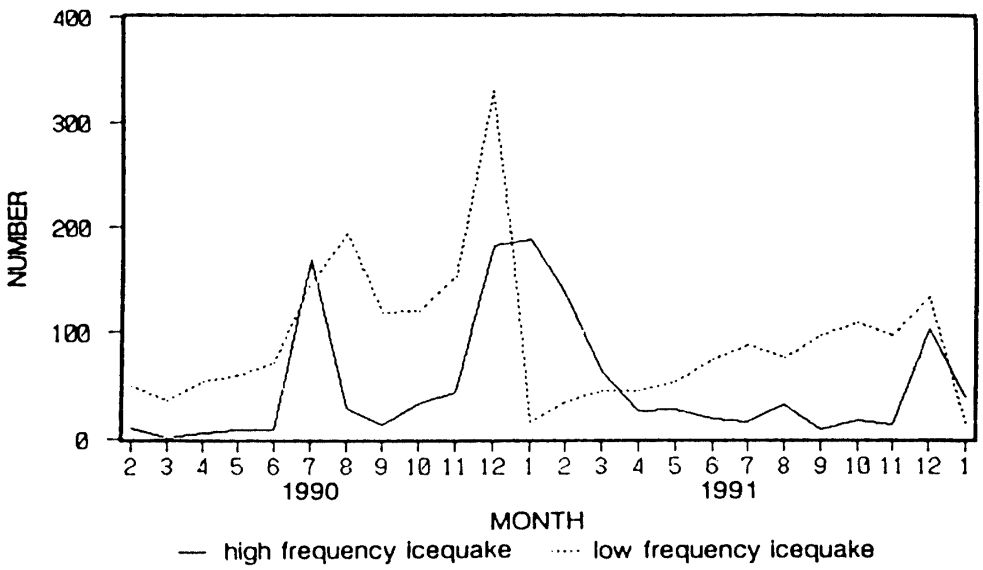


*Fig. 3. Monthly number of icequakes from February 1990 to January 1992. Solid line shows the numbers of the high frequency type and dotted line is the ones of the low frequency type.*

The average number of the low frequency type is 93 events per month ; however, the maximum number of icequakes in one day is 24 events on December 5, 1991. Otherwise there were less than 20 events per day.

The maximum monthly number of the low frequency type is 329 events, which is considered a swarm, recorded in December 1990. There was no swarm like activity of the low frequency type in daily numbers, but 10–20 events per day were recorded on 17 days in December 1990.

Concerning the monthly numbers, the numbers of both types change with nearly similar pattern as shown in Fig. 3. However, the daily numbers are extremely different. The total number of the high frequency type is about 1.8 times larger than that of the low frequency type. But the maximum daily number of the high frequency type is about one third that of the low frequency type. In December 1990, around ten icequakes of the low frequency type occurred every day, and the daily numbers of the high frequency type increased quickly from the end of the month. The large daily numbers of the low frequency type continued in the following two months.

The locations of the icequakes could not be determined because there was only one station in operation. As reported by KAMINUMA and HANEDA (1979), many sea-ice shocks were recorded by the seismographs at Syowa Station. The sea-ice shocks were characterized by high frequency waveforms and shorter duration. However, it is estimated from the waveforms that the icequakes of both types discussed here are not sea-ice shocks which occur around East Ongul Island. The icequakes appear to originate from the continental ice as concluded by AKAMATSU *et al.* (1990).

## 3. Tremor with an Icequake Swarm

Tremors are also observed frequently in addition to the two types of icequakes. The durations of tremors are from 10 s to around 10 min. Figure 4 shows an example of tremor recorded on December 31, 1990. The duration of this event was about 13 min and its amplitude was large compared with those of other tremors with long duration. Activity of the high frequency type icequakes increased before and after the tremor. Five icequakes of the high frequency type were recorded during 30 min from 18h00m as shown in the lower part of Fig. 4. There was another tremor recorded from 18h29m in Fig. 4. The tremor lasted only 2 min although the amplitude was larger than that of the previous one.

The daily numbers of the high frequency type icequakes are shown in Fig. 5 during 3 months from December 1990 to February 1991. The arrow in the figure shows the tremor. It appears that a series of activity started on December 15, 1990 and continued until the end of February 1991. The daily numbers increased quickly from December 28, and decreased quickly by March 1. About 30 icequakes were recorded during 6 hours after the tremor shown in Fig. 4. Some features of these occurrences can be understand from the lower part of Fig. 4.

No other information about the occurrences of tremors and icequake swarms is available during the period we have studied. There is no clear evidence to prove that the icequake swarm was caused by the tremor. This is the only time an

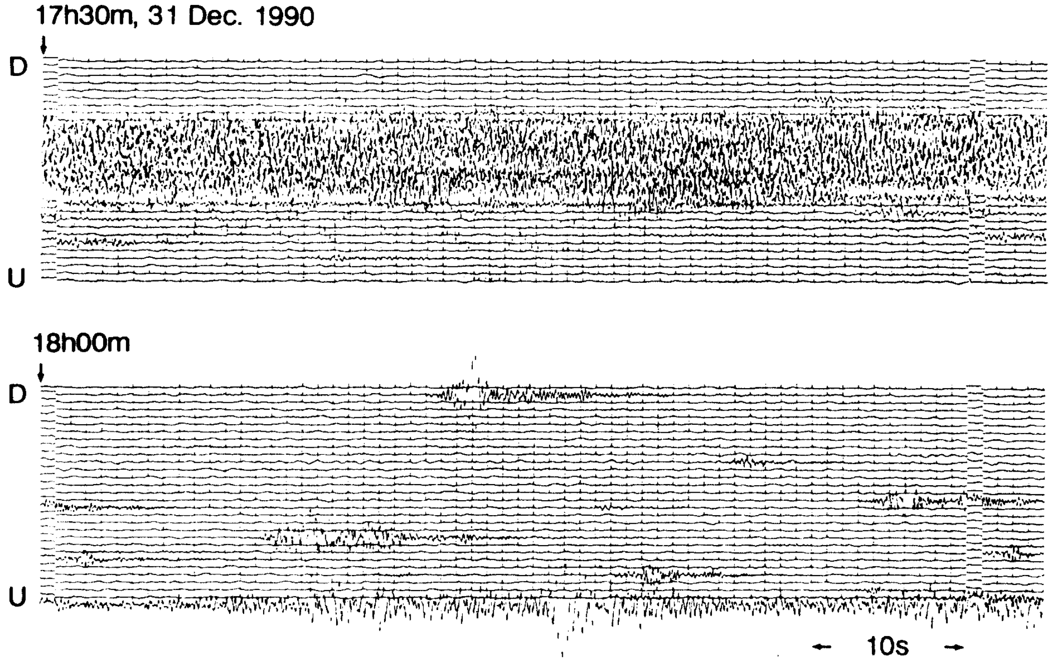


*Fig. 4. The seismogram of a tremor which started at around 17h40m on December 31, 1990 and accompanying icequakes of the high frequency type.*

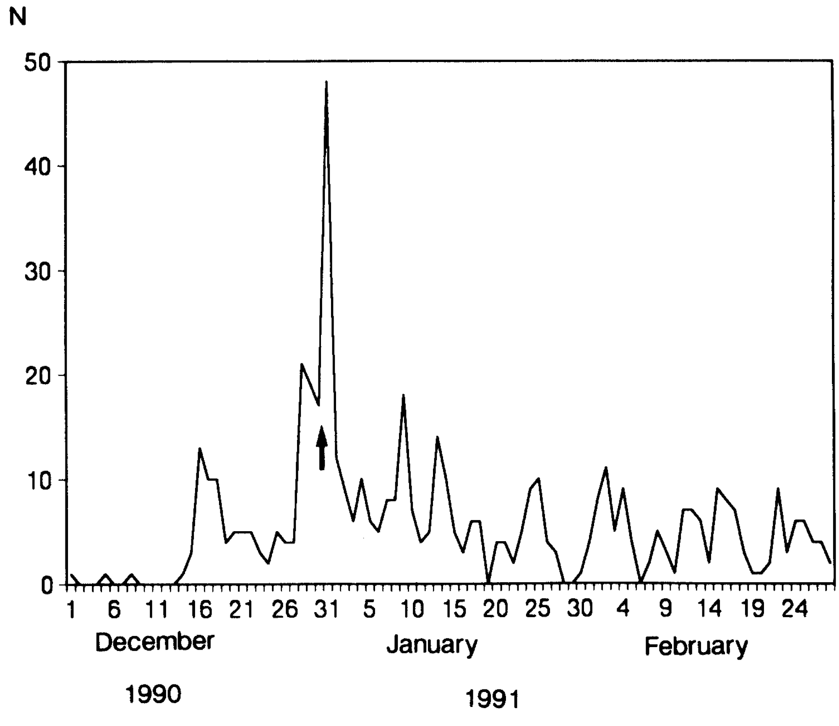


*Fig. 5. Daily numbers of high frequency type icequakes during the swarm-like activity from December 1990 to February 1991. The arrow shows a tremor of long duration.*

icequake swarm and a tremor have been observed at the same time. The tremor also appears to originate from the continental ice.

## 4. Conclusion and Discussion

Icequakes recorded at Syowa Station are studied. More than 3400 icequakes were recorded on the monitoring seismogram of the three-component short period seismograph during 24 months from February 1990 to January 1992. The characteristics of icequakes studied in this paper are as follows:

1) Icequakes are roughly divided into two groups, a high frequency type and a low frequency type (Fig. 2).

2) The total number of high frequency type icequakes is 1.8 times larger than that of the low frequency type.

3) There are swarm-like activities in the monthly numbers of both types (Fig. 3). However, only one icequake swarm of the low frequency type in the daily number was recorded. The other daily numbers of the high frequency type are less than 20.

4) A swarm like activity of the low frequency type was observed. The high activity continued mostly for a week accompanying a large tremor (Figs. 4 and 5).

5) Because the data are from a single station, the locations of icequakes are not determined, however all icequakes of both types and tremors might occur in the continental ice.

These results suggest that seismic monitoring at Syowa Station is useful to monitor movement of the Antarctic ice sheet. We speculate from previous work (KAMINUMA and HANEDA, 1979) that the high frequency type icequakes are continental icequakes occurring with daily change of oceanic tide. If a tripartite seismic network is operated, more detailed discussion will be possible concerning the origin of the two-type icequakes and tremors.

## Acknowledgments

The authors gratefully acknowledge Mr. I. KARAKAMA of NIPR for scaling and analyzing all the events. Messrs. K. NAGASAKA and M. YAMAMOTO maintained the seismographs at Syowa Station when they wintered in 1990-91 and in 1991-92 as members of the 31st Japanese Antarctic Research Expedition (JARE-31) and of JARE-32 respectively. Ms. M. MINEGISHI prepared all manuscripts.

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*(Received April 14, 1993; Revised manuscript received June 14, 1993)*